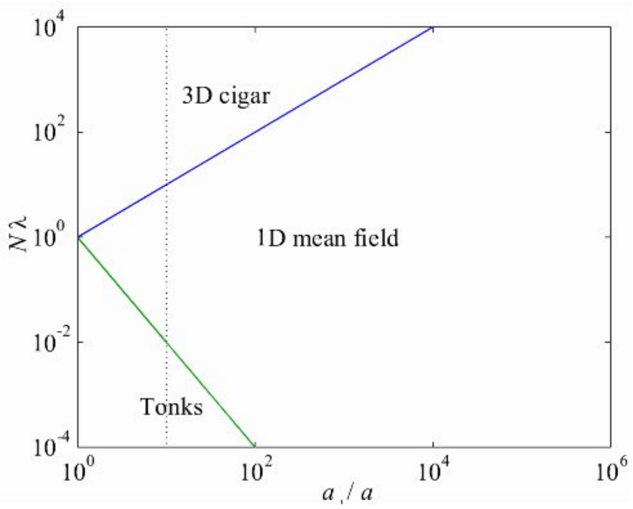
Report on our work with C. Menotti on ultracold bosons in low dimensional traps

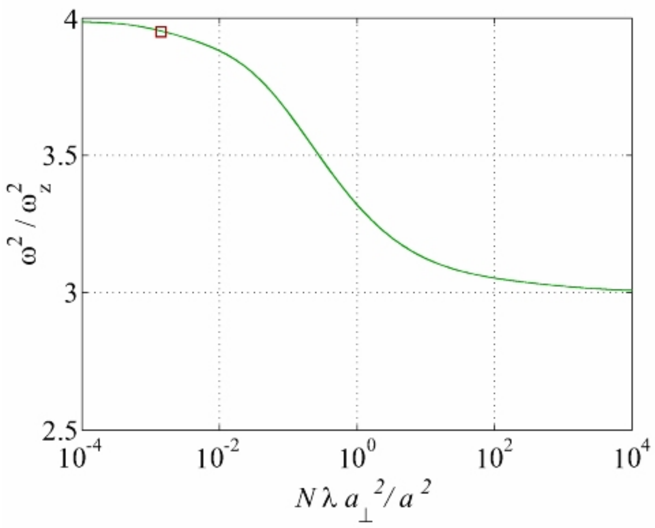
Recent experiments on trapped Bose-Einstein gases at low temperature have pointed out the occurrence of characteristic one-dimensional features. These include deviations of the aspect ratio and of the release energy from the 3D behaviour as well as the appearance of thermal fluctuations of the phase, peculiar of 1D configurations [1].
Interest in 1D interacting Bose gases arises from the occurrence of quantum features which are not encountered in 2D and 3D. For example, in 1D the fluctuations of the phase of the order parameter rule out the occurrence of long-range order even at zero temperature. Such systems cannot be, in general, described using traditional mean-field theories and require the development of a more advanced many-body approach.

In her work C. Menotti investigated the effect of dimensionality on the collective oscillations of an interacting 1D Bose gas at zero temperature trapped in a harmonic potential [2]. We together studied how to check experimentally her proposals using magnetic microtraps [3]. By changing the trap geometry we hope to observe the transition from the mean-field regime where the radial motion is frozen, to the Tonks-Girardeau limit of an impenetrable gas of bosons where the system acquires Fermi-like properties.
The following graph shows the phase diagram:



where N is the atom number, $\lambda=\omega_z/\omega_f$ the ratio of the trapping frequencies, and a_f/a the ratio of the axial oscillator length and the atomic scattering length.

As shown in the work of C. Menotti the frequency of the lowest compression mode provides a useful indicator of the different regimes. The behaviour of the collective oscillation frequencies is shown in the following graph as a function of the trap parameters:



$\omega^2/\omega_z^2 = 4$ is the value for the 1D Tonks gas described by the Lieb-Liniger theory, while $\omega^2/\omega_z^2 = 3$ is the result of a 1D mean field calculation.

Our estimations give hope to observe the phase transition between these two regimes by varying the axial and radial confinements, which can be changed independently in our wire traps.
The Tonks regime should be reachable by maximizing the radial and minimizing the axial confinement and by reducing the atomic density to the limit of detectability.
Assuming an atom number N=1000, the Rubidium 87 scattering length a=5.77 nm and trap frequencies radial $\omega_f = 2\pi$ 5 MHz, and axial $\omega_z = 2\pi$ 10 Hz one finds collective modes indicated by the red square in the previous graph, which is clearly very close to the Tonks regime.

The atom chip technology should then provide an efficient tool to explore the transition between the different regimes exhibited by such systems, pointing out the crucial interplay between the effects of quantum correlations and dimensionality.

[1] A. Goerlitz *et al.*, Phys. Rev. Lett. 87, 130402 (2001); F. Schreck *et al.*, Phys. Rev. Lett. 87, 080403 (2001); S. Dettmer *et al.*, Phys. Rev. Lett. 87, 160406 (2001).
[2] C. Menotti and S. Stringari, Phys. Rev. A 66, 043610 (2002).
[3] R. Folman, P. Krueger, J. Denschlag, C. Henkel, and J. Schmiedmayer,
Adv. At. Mol. Opt. Phys. 48, 263 (2002).